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New Standard Weir Design for Dredged Material Management Area, Jacksonville District

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STUDY OVERVIEW: Dredging supports ports and harbors and the nation's transportation infrastructure by maintaining or creating navigation channels, similar to the way that highway construction maintains or creates highways. One of the primary aspects of any dredging project is deciding where to place the dredged material. In basic terms there are only two choices; place the material in the water or place it on land. When dredged material is placed on land, the process is usually called 'upland placement of dredged material.' When placed upland, dredged material is usually accompanied by large amounts of water and a containment area is usually required to temporarily hold the water and permanently hold the dredged material. The containment area is known as a dredged material management area (DMMA), dredged material disposal facility (DMDF), confined disposal facility (CDF), or by similar nomenclature. In order to separate water from dredged material, a DMMA usually includes an outlet structure for letting supernatant water return to the natural water body from which it was entrained by the dredge. The outlet structure is usually a weir box. In general, DMMA weirs are designed with three major purposes in mind: 1) to retain all of the dredged sediment solids within the DMMA, 2) to let the excess water leave the DMMA and return to the natural water body, and 3) to prevent scour or resuspension of settled solids and control the release of water in such a way that suspended solids (usually measured with respect to turbidity) within the return water are kept to a minimum. A detailed discussion of weir design and operation for this purpose can be found in U.S. Army Corps of Engineers (USACE) Publications EM 1110-2-5027 and EM 1110-2-5025 (Headquarters, USACE 1983, 1987).

PURPOSE: This Dredging Operations and Technical Support (DOTS) Program technical note presents a new weir design utilized by the USACE Jacksonville District. The new design is less expensive, safer, and more easily constructed. It also has inherent redundancies and a longer life cycle (see Figure 1). The carrier water from the dredged

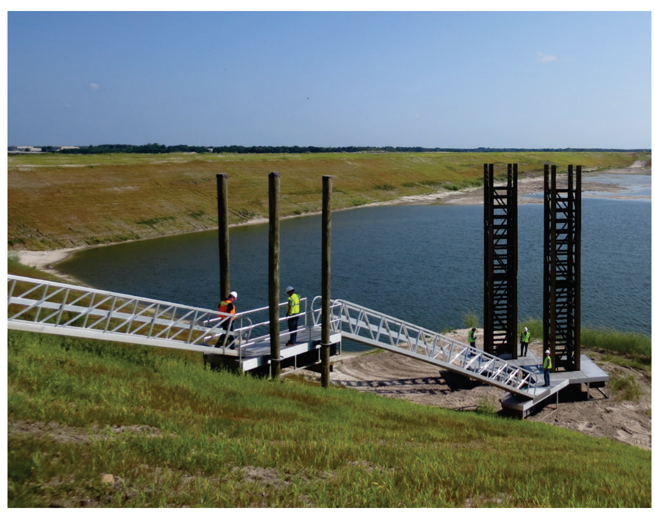

Figure 1. Set of 38-ft-tall, 4-ft x4-ft box riser weirs (under construction) with dual-segment gangway to floating dock access, Bartram Island Cell B2, Jacksonville, Florida.

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material slurry (water plus dredged solids) that is pumped into a DMMA during dredging must be decanted. The volume of carrier water is several times greater than the amount of dredged solids remaining within the site; thus, if the weir system has issues, the entire project is at serious risk (Fowler et al. 1999).

BACKGROUND: Since the 1960's, the US Army Engineer District, Jacksonville and its local project sponsors have maintained a standard or traditional design for DMMA weir decanting structures. This structure design is known as the "Higgy" after its inventor, Norman Higginson (see Figure 2). This traditional design was developed to provide water control for the freshwater drainage canal systems of south Florida. For decades, this design's use has spread throughout the United States within DMMAs and where water elevation control is necessary. The basic design has remained unchanged from its original concept, which consists of a corrugated half pipe riser structure with I-beam channels for holding weir board stop logs to control the weir crest elevation. These weir structures utilize two weir stacks, wooden weir boards, coated corrugated metal, and corrugated outfalls. From a functional standpoint, the structures are complex field fabrications that are pile-supported with very limited weir face access. Half-pipe risers typically require three to eight structures to be installed in a DMMA to meet the minimum weir crest length requirements based on site size and dredge size (Francingues et al. 2001, Walski and Schroeder 1978).

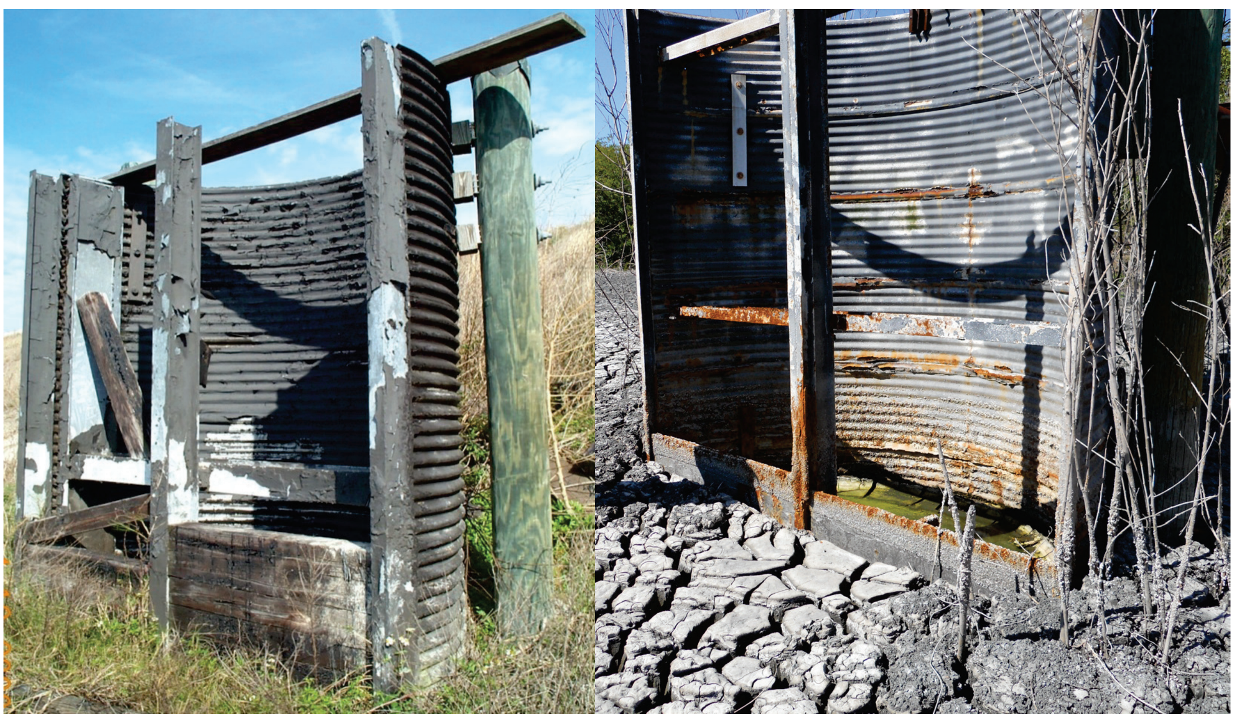

Figure 2. Historic half-pipe weir structure, consisting of a pile-supported corrugated riser and corrugated outfall pipes, with field-installed corrosion inhibiting coatings, Buck Island (right), Jacksonville, Florida and DMMA 2-D (left), Tampa, Florida.

INHERENT CONCERNS WITH THE TRADITIONAL DESIGN: The designs typically used for weir structures inherently involve the following issues:

- *Safety.* Commonly these weir installations include no working platform. As the water level within the DMMA rises and falls, weir boards need to be added or removed from the weir structure. The weir structure is surrounded by water and typically the only access to these boards is by boat. The traditional 4-in. x 6-in. timber weir boards are heavy and cumbersome, making the work of adding or removing the boards dangerous.
- *Leakage of the weir boards.* After becoming wet, the wooden weir boards swell and warp, which tends to cause gaps between the boards. To account for the swelling, the boards must be cut a little shorter than would otherwise be required to get a good tight fit. As a result, a large amount of water leaks around and through the riser stack of weir boards. This requires secondary sealing measures in the form of plastic sheeting, geotextiles, and/or burlap.
- *Corrosion of asphalt-coated metal.* The traditional thick (0.5-in. to 0.75-in.) asphalt coating on the metal parts breaks down in a matter of a few years, leaving the metal exposed to the elements. In a short time, corrosion can eat all the way through sheet metal and corrugated parts. Corrosion of the corrugated outfall pipes, if undetected, can lead to leakage and piping through the earthen embankment and cause dike failure.
- *Weir board flotation.* Blockage of the outfall pipe or a significant drawdown event can cause the water to “back up” into the riser stack above the level of the weir boards. This, in turn, causes the weir boards to float up due to their inherent buoyancy. When the water level drops, the weir boards usually do not return to their original level position; instead, they usually become “jammed” at an angle, leaving large gaps between the boards and an open flow path for water and mud to escape uncontrolled from the DMMA.
- *No backup shut-off capability.* The weir board flotation issue mentioned above highlights the inherent weakness of this design in the case of an uncontrolled release of material from a DMMA. Once it begins, there is no back-up system in place to stop the uncontrolled release of mud at depth within a weir stack.
- *Field fabrication.* The erection of half-pipe weirs requires the driving of piles and field torch cutting through the corrugation for attachment points. This is a difficult and time-consuming operation, resulting in leakage at each attachment point and an increase in discharge turbidity.
- *Numerous penetrations through the dike.* Due to the number of half-pipe structures necessary to meet the minimum weir crest requirement, at least twice the number of outfalls (or a baffle system) is required in the traditional weir design versus the new design.

CONSIDERATIONS OF NEW WEIR DESIGN: The three basic tenets that guided this new design were:

1. Simplicity
2. Flexibility
3. Redundancy

The new outlet structure design utilizes dual coal-tar epoxy-coated steel box riser weirs on a single concrete slab foundation (see Figure 3). This single foundation ensures that the weir crest elevations are identical at all times. This style improves overall design simplicity as a result of less structures/pieces, shop fabrication, and ease of installation. The concrete foundation resists differential settlement and is sized to counteract the structure's displacement buoyancy. The new product is flexible in that it can be utilized in various locations, can be easily extended vertically, and the weir crests can be widened as necessary. For redundancy, weir structures are placed in pairs. Each metal box weir replaces the equivalent of at least two half-pipe weir structures, further reducing the number of structures and discharge pipes passing through the DMMA's embankment. This new box riser weir system can meet the typically required weir crest length of 24 to 40 linear feet with fewer overall structures and outfalls. The new structures are typically offset from the DMMA interior levee embankment toe to allow for the DMMA to be raised in the future when the initial storage capacity has been expended.

Figure 3. Bartram Island Cell F floating dock in use with composite weir boards removed and stacked on the dock's deck from two sides of each box riser.

OPERATIONAL CHARACTERISTICS: The main feature of the new design that greatly increases the safety and operability of the disposal area weirs is the floating dock access. The pontoon floats are located at the far corners of the dock system out of the weir flow path. This

stable platform is utilized for the insertion or removal of weir boards and moves workers out of the disposal area's interior, where small boats are typically employed to insert and pull waterlogged timber boards. Other improvements associated with this new design include high-density polyethylene (HDPE) outfall pipes and an internal emergency shutoff flap gate.

STRUCTURAL DESIGN: The new outlet structure design utilizes dual coal-tar epoxy-coated steel box riser weirs on a single concrete slab. Additional design features are listed below.

- The main structural system for the steel box riser consists of standard structural steel channels; these members are far more corrosion resistant than corrugated sheet metal. These members serve a dual purpose. Their primary purpose is serving as the vertical members of the structure, but they also serve as guides for the weir boards. For taller weirs, greater than 20 ft tall, the channels accommodate diagonal bracing used to stiffen the structure. These diagonal braces are standard square hollow steel sections (HSS). For axial loading, square HSS sections are the most efficient sections due, in part, to their symmetry, making them ideal for this application.
- The single concrete slab foundation was designed to resist differential settlement, wind loading, overturning, cracking, and flotation. Marine concrete (United Facilities Guide Specifications (UFGS) 03 31 29) was used to ensure longevity of the concrete in a marine environment. The specified minimum 4 in. of concrete cover provided the primary protection mechanism against chemical deterioration and corrosion-related damage to the steel reinforcement.
- The coal-tar epoxy coating was chosen to prolong the life of the structure. These structures will see many wet/dry cycles in a saltwater environment that would corrode an uncoated steel structure rather quickly. Coal-tar epoxy has the toughness, adhesion, UV resistance, and thermal stability of an epoxy combined with the extremely high moisture resistance afforded by the coal tar (EM 1110-2-3400 (Headquarters, USACE 1995)).
- In reference to fabrication of the weirs, contractors are allowed the following options. They may either fabricate the entire height of the weir as one unit or fabricate multiple units and bolt the units together in the field. The latter is depicted in the plan set to ensure adequate connections between units, should this option be chosen. These options give the contractor flexibility in shipping and erection of the weirs.

HYDRAULIC DESIGN: The riser weirs are typically oriented so that weir faces are angled 90 degrees apart from each other, as shown in Figures 1, 4, 5, 6, and 8. This allows the installation distance between the weirs to be one-half the distance that would be required if weirs were installed "square" to one another, as shown in Figures 3, 7, and 9. Increasing withdrawal depth mixing due to increasing flow is the factor that must be addressed in the design layout. The rule of thumb employed when designing the layout for box risers is to allow three times the weir crest length of space between weir crests when they are directly facing one another. When the weir crest faces are angled 90 degrees apart, this requirement is relaxed to one and one half times the weir crest length. This rotation of the weir orientation reduces the slab's footprint and allows for a thicker monolithic structure utilizing the same volume of concrete, thus reducing the slab's required steel reinforcement.

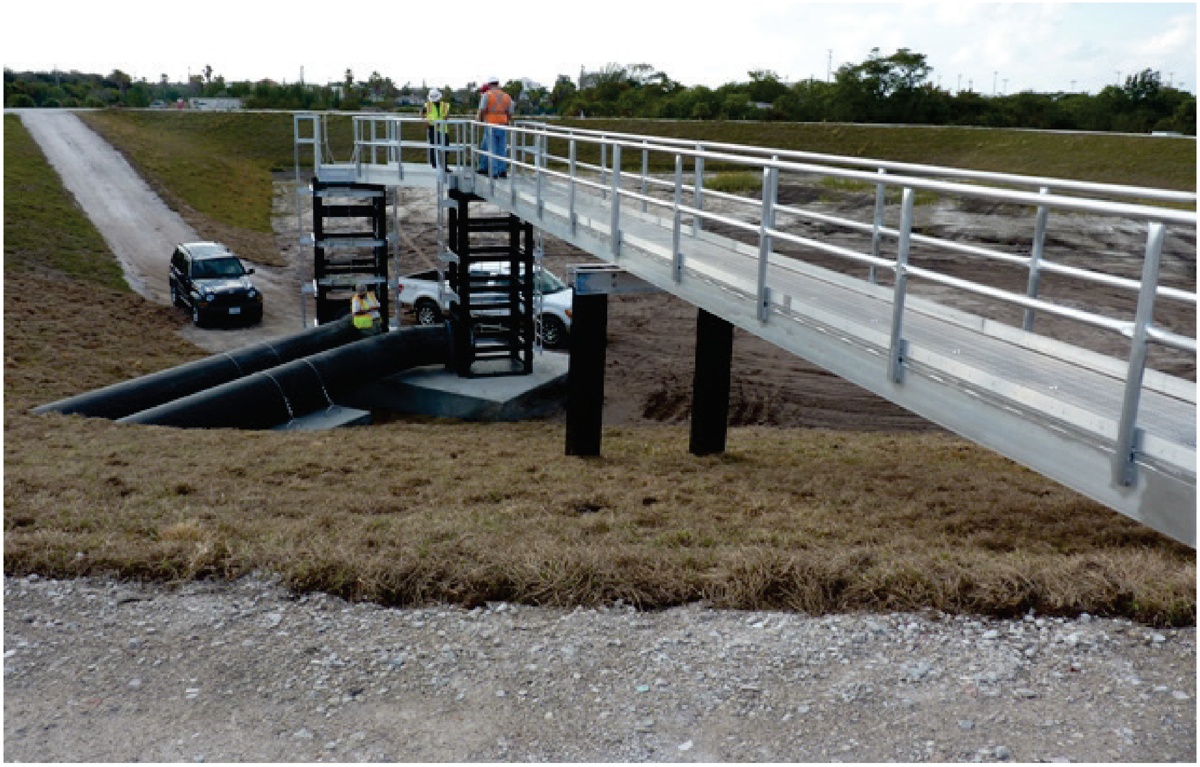

Figure 4. Set of 12-ft-tall, 4-ft x 4-ft box riser weirs with top access, MSA-641A, Delray Beach, Florida.

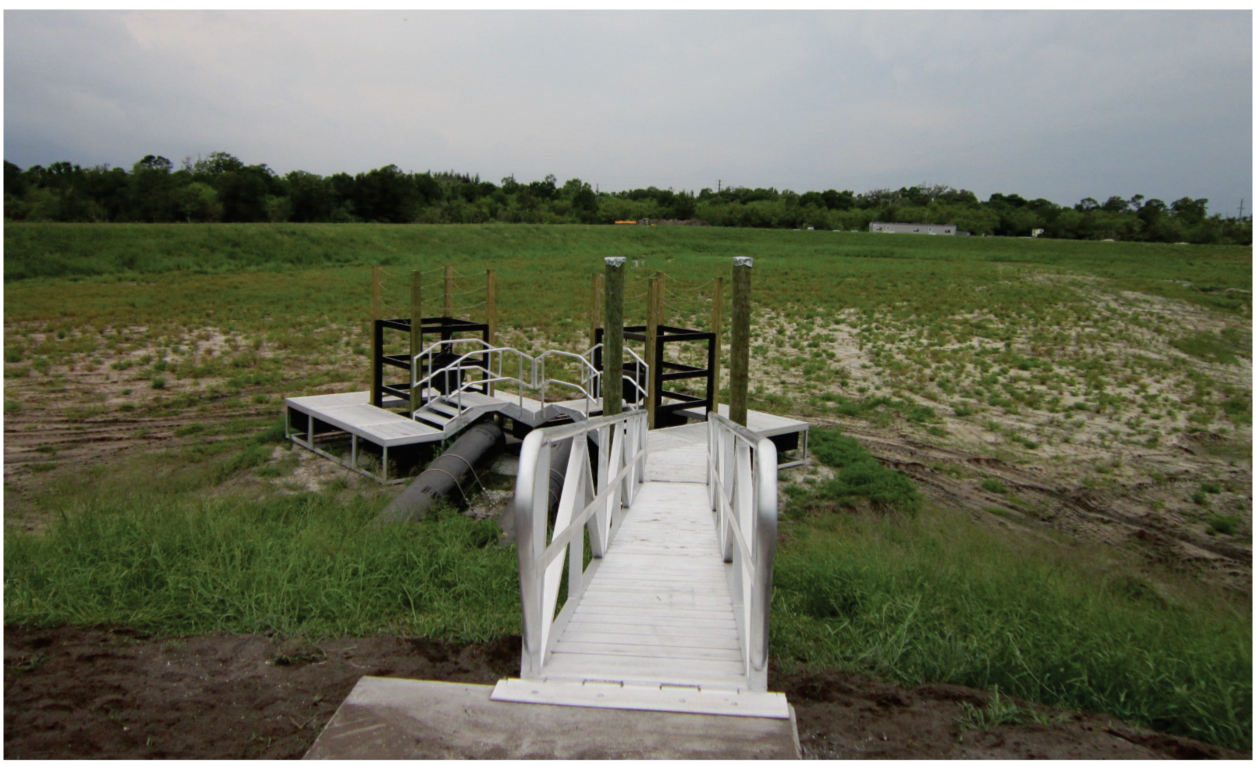

Figure 5. Set of 8.5-ft-tall, 5-ft x 5-ft box riser weirs with floating dock and gangway access, DMMA IR-2, Sebastian, Florida. Photo credit David May, Brance Diversified.

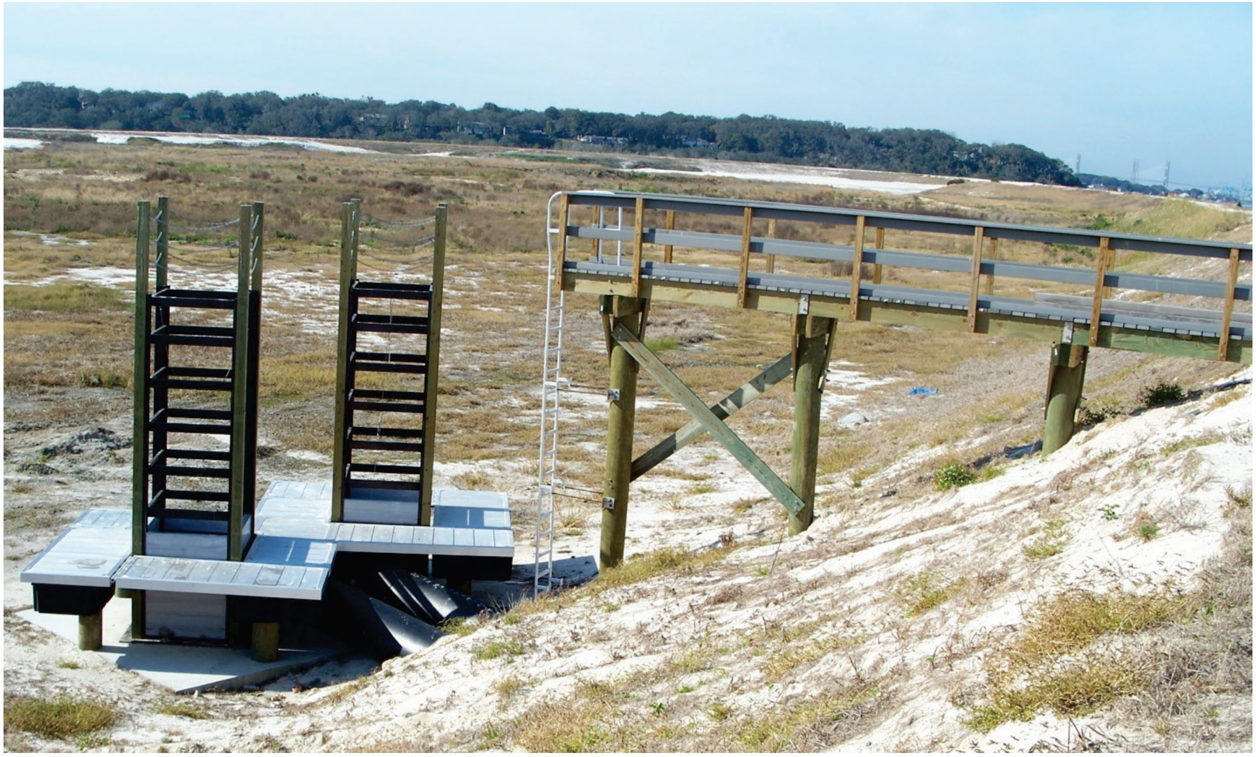

Figure 6. Set of 16-ft-tall, 4-ft x 4-ft box riser weirs with floating dock access, Buck Island, Jacksonville, Florida.

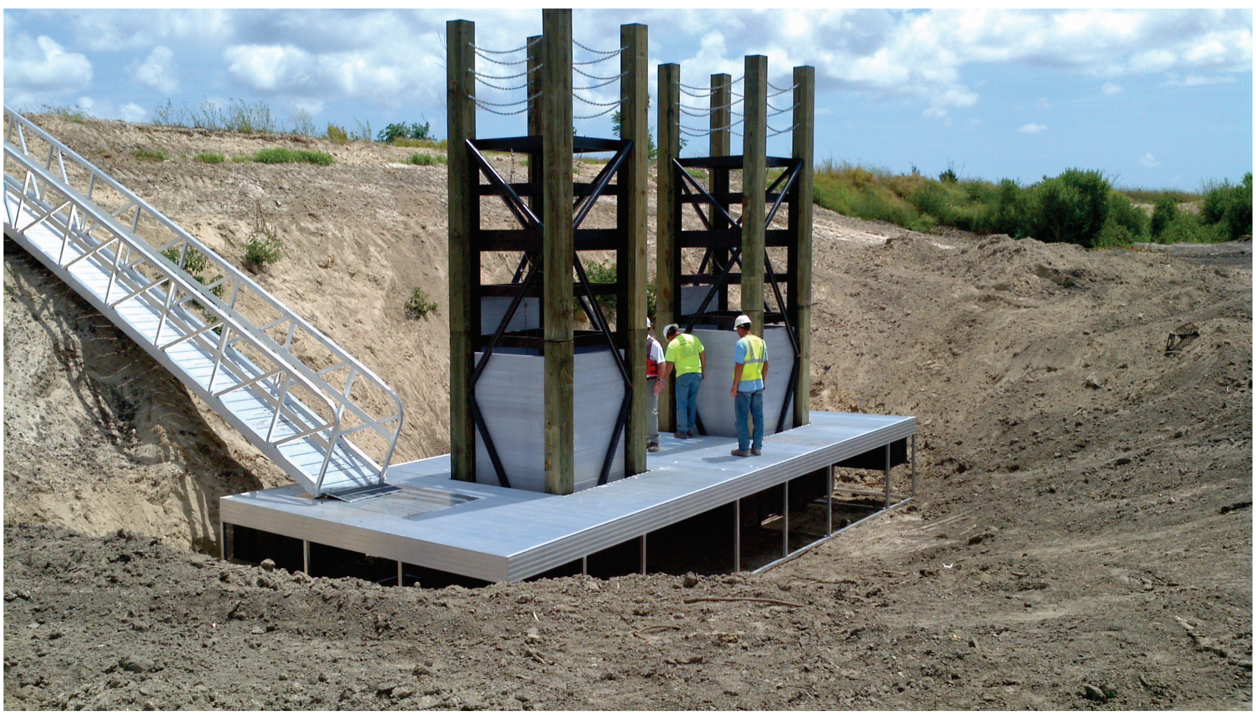

Figure 7. Set of 18-ft-tall, 4-ft x 4-ft box riser weirs with gangway to floating dock access, Bartram Island Cell F, Jacksonville, Florida.

Figure 8. Set of 28-ft-tall, 5-ft x 5-ft box riser weirs (under construction) with dual-segment gangway to floating dock access, Bartram Island Cell A, Jacksonville, Florida. Photo credit Jose Bilbao.

Figure 9. Florida Inland Navigation District site NA-1 designed by Taylor Engineering. Set of 11-ft-tall, 4-ft x 4-ft box riser weirs with gangway to floating dock access, DMMA NA-1, Fernandina, Florida. Photo credit Mr. Robert J. DiRienzo, Taylor Engineering.

Orienting the weirs at 90 degrees to one another allows the outfalls to be brought together for a reduced notch cut into the dike on rehabilitation projects. This also reduces the quantity of granular fill wrapping required to eliminate piping issues along the outfall. The outfalls employed for this design are HDPE DR 26 solid, smooth-walled continuously fused pipe. The use of welded plastic pipe removes material and joint degradation concerns traditionally associated with metal or concrete pipes.

INSTALLATION OF RISER STRUCTURES: The use of prefabricated, relatively light steel box riser structures allows excavators, which are typically onsite already, to pick and set the boxes on the slab. This removes the need for a crane and all of the associated costs. The process of installing these riser structures onto the slab takes only a matter of minutes.

INTERNAL WEIR FLAP GATES: Internal weir flap gates were included so as to have an emergency discharge shutoff system in the event of a weir board malfunction or extreme water quality issue. Several manufacturers of off-the-shelf flap gate products meet the material and design requirements (see Figure 10). However, given the corrosive environment that these flap gates are going to be installed in, only coal-tar epoxy-coated steel, marine grade aluminum, and 304 or 316 stainless steel products are recommended. The costs of these various products range from approximately $500 to $5,000 each. The flap gates are held in the open position by a 316 stainless steel cable shackled to the top of the weir frame. Quick-release pelican clips are

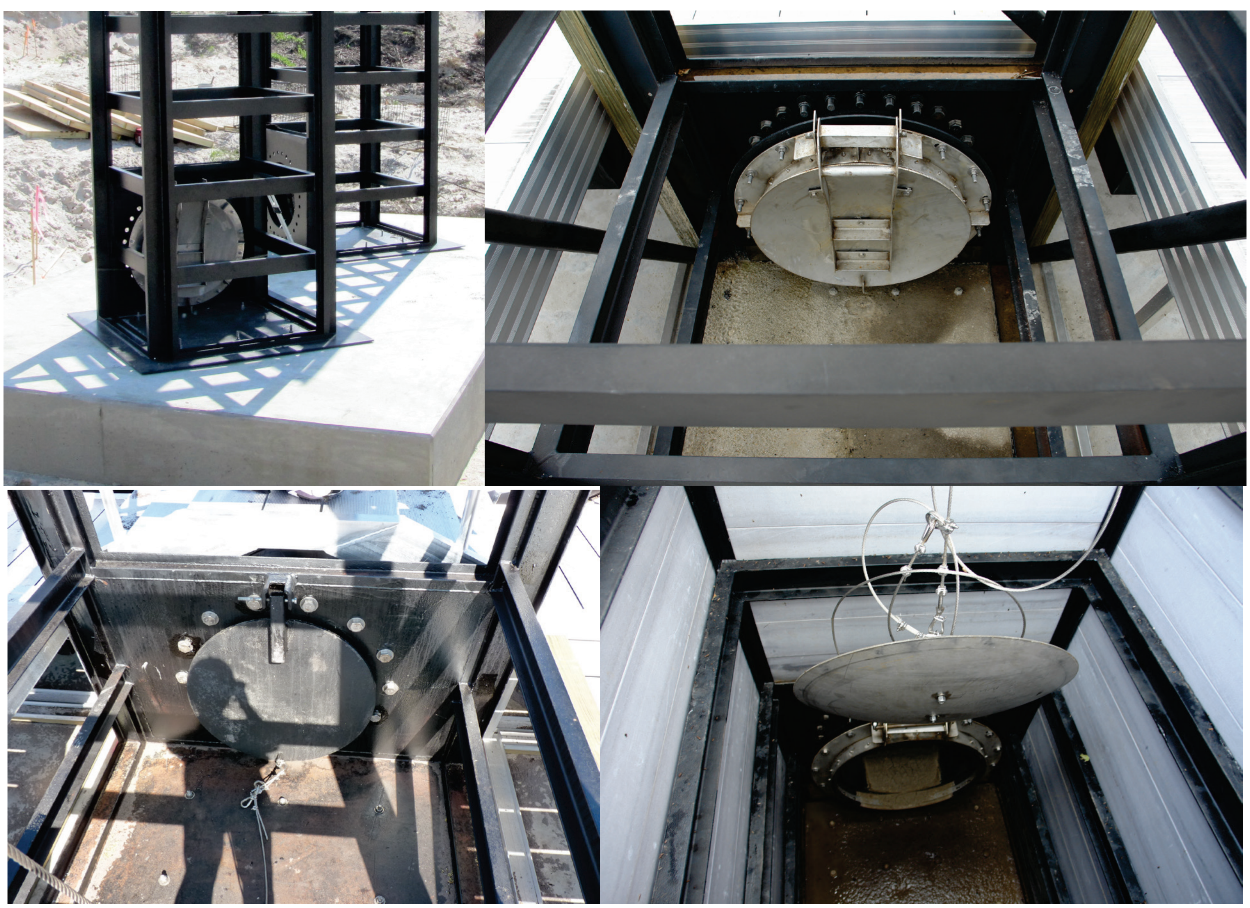

Figure 10. Internal weir outfall flap gates.

placed approximately every 5 ft along the cable to allow for easy closing of the flap gate regardless of the water elevation at the weir. A loop of cable is left at each pelican clip to allow for the complete closing of the flap gate while ensuring that the cable is still connected to the top of the weir. Once the internal flap gate is closed and water within the weir stack has created enough pressure to seal the gate, it will be impossible to reopen the flap gate without removing the water from the inside of the box, thus reducing the water pressure. This internal weir flap gate emergency shut-off system provides an additional protocol to ensure that environmental compliance can be maintained at all times.

PERMANENT OUTFALL INSTALLATION: HDPE outfall pipes were employed due to their non-corrosive nature. Permitting and installing the outfalls permanently allows for future cost savings versus the traditional operation of extending the outfalls for each dredging event and then removing them once dredging has been completed (see Figure 11). Temporary outfall results in a diminished fringing marsh that is periodically impacted by construction activities, thus allowing for increased upland erosion. Having temporary outfalls also does not allow for long-term site management including ditching and dewatering operations. One of the primary reasons permanent outfalls are not utilized more often is due to marine wood borers that can quickly destroy any cross members cradling the outfalls. To mitigate this design issue, composite beams were utilized (instead of timber) to cradle the outfalls.

Figure 11. Elevated 30-in. outfall pipes minimize wetland impacts at Bartram Island Cell B2.

COMPOSITE WEIR BOARDS: A significant innovation of the new weir system is the inclusion of composite hollow weir boards, which are lighter and easier to handle, and therefore safer than the standard wooden nominal 4-in. x 6-in. weir boards (see Figures 12 and 13). More importantly, composite boards have negative buoyancy, so there is no potential for the weir boards to float and become askew during drawdown operations. The initial cost of these composite weir boards is approximately four times greater than their treated timber counterparts. However, their strength is several times greater and they are not subject to rot. Their use also removes the need for periodic excavation around the weir structure for timber weir board inspection and replacement.

OPERATOR IMPRESSIONS: The new box riser weir system has been used on several recent dredging contracts administered by the Jacksonville District and Jacksonville Port Authority. Manson Construction Company utilized the new weir system during a dredging project with disposal at the Buck Island DMMA in January 2013. The Corps contacted Manson to discuss their initial impressions of the updated weirs. Freddie Harold was Manson's employee in charge of operating the weirs to control the water level in the DMMA and the turbidity of the water leaving the site. Overall, Mr. Harold stated that the new weir system is a vast improvement over the traditional style, which was difficult to access during active dredging. This access problem was compounded by the fact that the wooden weir boards used for the old weirs were heavy and cumbersome. He also stated that the new system is much safer due to the improved access and that installation and removal of weir boards is much easier due to the better access and the lighter materials utilized. He went on to state that the new weir boards are much more uniform and fit tighter than the wooden boards used in the old design. The increased weir length and the duplication of weirs offer greater flexibility in controlling the water level in the disposal areas. He also stated that working from the floating platforms was much preferable to installing weir boards from ladders or from small boats, as was required under the old system. Based on the opinion of this contractor, the new weir system seems to be a vast improvement over the old-style weirs.

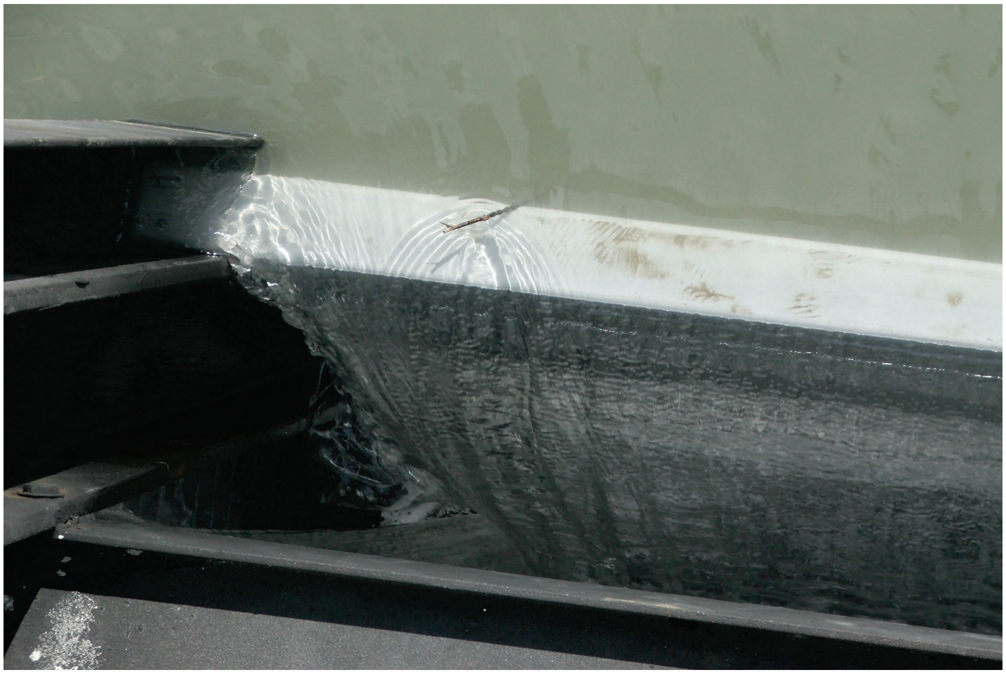

Figure 12. Plan view of composite weir boards DMMA M-5, Stuart, Florida.

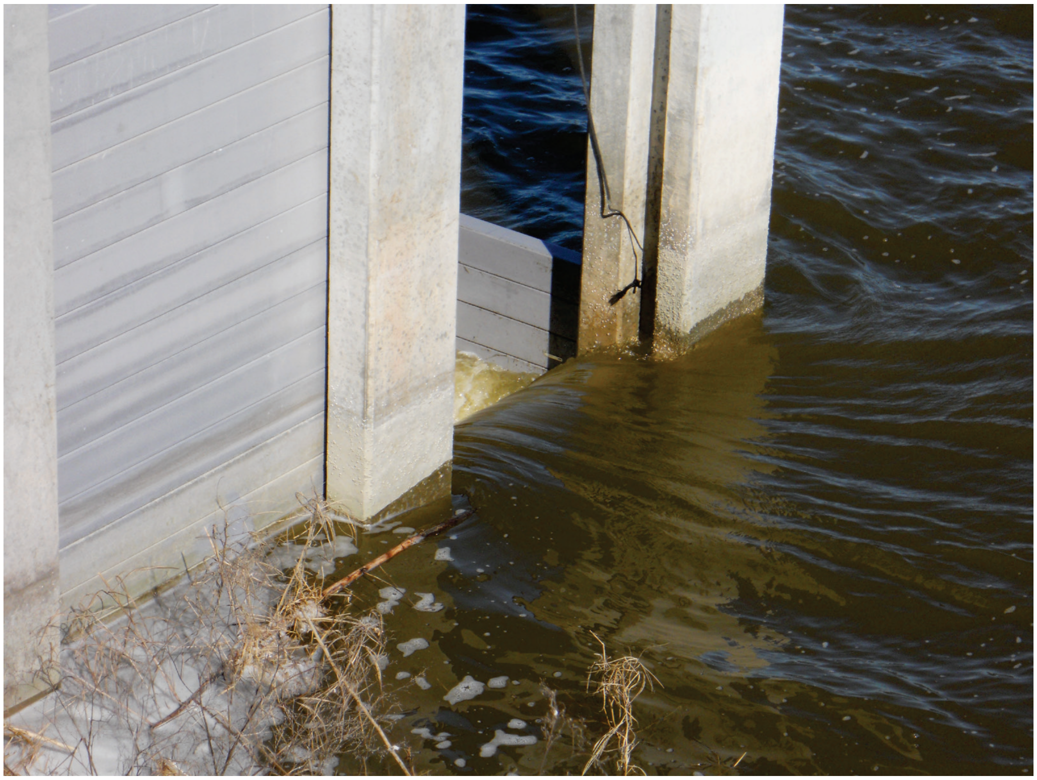

Figure 13. Composite weir boards in concrete box weir DMMA 2-D, Tampa Bay, Florida.

COST ANALYSIS: From a financial standpoint, the new weir design has a significant impact on cost. An extensive value engineering study was performed on the new design in 2011, which identified significant cost savings over the life of the project as well as during its initial construction. As part of this study, the last two traditional half-pipe installation contract costs were compared to the first three new box riser contracts. The base assumptions of this analysis were as follows:

1. The traditional design has a functional life of 10 years, while the box design has a functional life of 25 years.
2. There would be a project design horizon of 50 years.
3. The box riser weir includes a contractor's design cost of $100 K.
4. The Federal discount rate of 4.125% was applied to the each design.

The present value initial cost savings of the dual-box riser weir design over the traditional half-pipe style is $200 K, 28% of the initial cost. The life cycle savings of the box design is roughly $1.2 M for a total economy of approximately $1.4 M per site over 50 years. Larger multiple-cell DMMA's requiring two or more sets of new box riser weirs would realize at least twice the savings.

The same value engineering analysis was performed on the two most recent dual-box riser projects (Bartram Island Cells A and B2 and Bartram Island Cell F). These projects differ from the projects in the 2011 analysis in that they are on an island with no road access, resulting in far more difficult construction logistics. The new weirs at Cells A and B2 are 28 and 38 ft tall,

respectively. With this design height, the traditional half-pipe style requires that two sets of weirs be installed at different elevations to equal the functional performance of either of these new weirs. In Cell F, the set of dual-box riser weirs replaced six traditional half-pipes. Two of the outfalls from the existing weirs were slip-lined, while the remaining pipes were grouted in place. As part of this analysis, the last two traditional half-pipe installation contract costs were compared to the most recent box riser contracts. The base assumptions of this analysis were the same as above, except that the 2013 Federal discount rate of 3.75% was applied. The initial cost savings of the dual-box riser weir design over the traditional half-pipe style was $164 K. The life cycle savings of the box design is roughly $1.3 M, for a total economy of approximately $1.45 M per site over 50 years.

CONCLUSIONS: This technical note describes a new innovative dual-box riser system that has become the new standard for the Jacksonville District. Customers and consultants that frequently work with the Jacksonville District have recognized the cutting edge nature of this design and have adopted the design as their standard for projects, even those outside the Corps. The new dual-box riser system is less expensive to construct, requires less maintenance, offers safer and easier operation, and can be installed in a vast array of geotechnical site conditions.

New weir design installations:

Florida Intracoastal Waterway sites: MSA-641A, IR-2, NA-1; Jacksonville Harbor sites: Buck Island Cells A and B, Bartram Island Cells, A, B2, and F.

Future scheduled installations:

DMMA O-7 (Florida Inland Navigation District, Okeechobee Waterway).

Disposal sites utilizing composite weir boards instead of timber:

Tampa Harbor: DMMA 2-D, DMMA 3-D; Florida Intracoastal Waterway sites: DMMA M-5, and Lost Creek Island, Ponce Inlet, Florida.

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